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SCIENCE 8

MODULE 3

LIGHT AND OPTICAL SYSTEMS

Learning Technologies Branch

Alberta LEARNING

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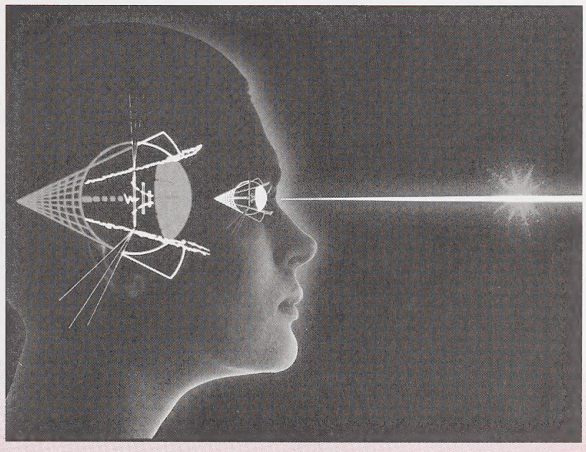
SCIENCE 8

LIGHT AND OPTICAL SYSTEMS 3



Learning Technologies Branch

Alberta LEARNING

Science 8
Module 3: Light and Optical Systems
Student Module Booklet
Learning Technologies Branch
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The Learning Technologies Branch acknowledges with appreciation the Alberta Distance Learning Centre and Pembina Hills Regional Division No. 7 for their review of this Student Module Booklet.

This document is intended for	
Students	✓
Teachers	✓
Administrators	
Home Instructors	
General Public	
Other	

You may find the following Internet sites useful:

- Alberta Learning, **http://www.learning.gov.ab.ca**
- Learning Technologies Branch, **http://www.learning.gov.ab.ca/ltb**
- Learning Resources Centre, **http://www.lrc.learning.gov.ab.ca**

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WELCOME

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MODULE 2 Cells and Systems

MODULE 3 Light and Optical Systems

MODULE 4 Mechanical Systems

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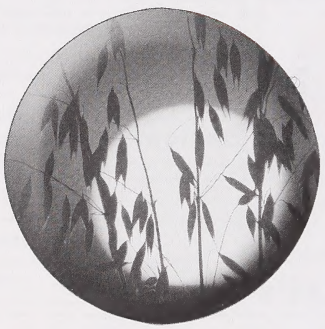

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Resources

Textbook

To complete the course, you need the textbook *ScienceFocus 8*.

Multimedia

Attached to Module 1 of this course is a CD titled *Science 8 Multimedia*. This CD contains multimedia segments designed to help you better understand particular concepts presented in this course. Ask your teacher or home instructor if you need help using this CD.

Materials and Apparatus

A list of materials and apparatus is given on page 10 of each Student Module Booklet. These items are needed to complete the module. Some of the materials and apparatus may be provided at your local school lab. If you don't have access to a school lab, you will need to get the loan kit. Talk to your teacher for more information.

Before You Begin

Organize your materials and work area before you begin: Student Module Booklet, textbook, notebook, pens, pencils, and so on. Make sure you have a quiet area in which to work, away from distractions.

Because response lines are not provided in the Student Module Booklet, you'll need a looseleaf binder or notebook to respond to questions and complete charts. It's important to keep your lined paper handy as you work through the material and to keep your responses together in a notebook or binder for review purposes later.

Refer to the Planning Ahead page for directions on what you need to do before you start this module.

Good luck!

Icons

This is one of five Student Module Booklets for Science 8. As you progress through this module, you will meet several icons.

Do Ahead

Some preparation must be started well ahead of the activity or investigation. E.g., start the seedlings for the investigation in Lesson 3.

Teacher or Home Instructor

The teacher or home instructor should be contacted for help, approval of some procedure, or checking answers.

Assignment Booklet

Work needs to be done in an Assignment Booklet.

Safety

You must be very careful when you see this symbol.

Textbook

A reference is made to *ScienceFocus 8*, the student textbook for this distance learning course.

Internet

This is a reference to the Internet. **Note:** Any Internet website given is subject to change.

Multimedia

This is a reference to the *Science 8 Multimedia* CD.

Overview

From the moment you woke up today, you have used the properties of light to carry out your daily activities. Light provides you with a great deal of information about the world around you. Your eyes detect the colour, brightness, position, size, shape, and texture of objects as light interacts with matter. The digital display of your clock, a flickering flame, and the Sun are all sources of light.

What is the nature of light? What properties of light allow you to see an object? The study of light has gone on from earliest human history. As a result, a great deal is known about its nature and characteristics.

Section 1
The Nature and Behaviour of Light

Section 2
Vision and Optical Devices

In this module you will explore some of the fundamental properties of light. You will investigate how these properties are applied in optical devices to extend human vision. You will also learn how these optical devices have led to advances in many areas of science.

Assessment

The booklet you are presently reading is the Student Module Booklet. It will show you, step by step, how to advance through Module 3: Light and Optical Systems.

This module, Light and Optical Systems, has two sections. Within each section your work is grouped into lessons. Within the lessons there are readings, investigations, activities, and questions for you to do. By completing these lessons you will discover scientific concepts and skills, develop a positive attitude toward science, and practise or apply what you have learned.

Suggested answers in the Appendix of this Student Module Booklet will provide you with immediate feedback on the answers to questions in the lesson. Your teacher or home instructor will also provide you with feedback on your progress through the module.

At several points in this module you will be directed to an accompanying Assignment Booklet. Your grading in this module is based on the assignments you submit for assessment. In this module you are expected to complete two section assignments and a Final Module Assignment.

The mark distribution is as follows:

Assignment Booklet 3A	
Section 1 Assignment	48 marks
Assignment Booklet 3B	
Section 2 Assignment	32 marks
Final Module Assignment	38 marks
TOTAL	118 marks

Planning Ahead

Here is a list of materials and apparatus you will need to complete this module.

Section 1

- ❑ a solar-powered calculator, if possible
- ❑ two identical black film canisters
- ❑ aluminum foil
- ❑ a book
- ❑ a lamp without a shade
- ❑ a 60 W light bulb
- ❑ a 100 W light bulb
- ❑ measuring tape
- ❑ a sharp knife
- ❑ a large cardboard box
- ❑ masking tape
- ❑ a ray box, if possible
- ❑ a small flat plane mirror (5 cm by 5 cm)
- ❑ a protractor
- ❑ a ruler
- ❑ a wooden pencil
- ❑ four sheets of blank paper
- ❑ a cup or bowl of opaque material
- ❑ a coin
- ❑ a plastic cup with transparent sides
- ❑ a transparent watertight tray—only needed if a ray box is available
- ❑ liquids other than water, such as vegetable oil, liquid soap, and liquid honey that are non-toxic and non-corrosive—only needed if a ray box is available

Note: Use only common household liquids. After they have been used in the investigation, they may be disposed of by flushing them down the toilet or by other sensible methods.

Section 2

- ❑ a flashlight
- ❑ a comb
- ❑ a concave lens
- ❑ two convex lenses
- ❑ plastic wrap
- ❑ a candle
- ❑ matches
- ❑ a compass from a geometry set
- ❑ a dish to hold the candle
- ❑ a book
- ❑ a pair of scissors
- ❑ a ruler
- ❑ a tape measure or a metre stick
- ❑ masking tape
- ❑ a black Bristol board (20 cm by 15 cm—three pieces) or cardboard
- ❑ white paper

For Section 2: Lesson 1, see if you can have a pair of glasses handy.

For Section 2: Lesson 1, try to borrow a camera. If possible, get one that allows you to adjust a focusing ring for various distances. Identify the parts you read about in the lesson.

If you're going to the library soon, you may want to start library and Internet research for "Think and Link Investigation 3F" on page 45 of Section 2: Lesson 1.

If you have access to the Internet, you may want to check out some of the links for this module ahead of time. Go to the following site:

http://www.mcgrawhill.ca/school/booksites/sciencefocus+8/student+resources/toc/index.php

Section 1

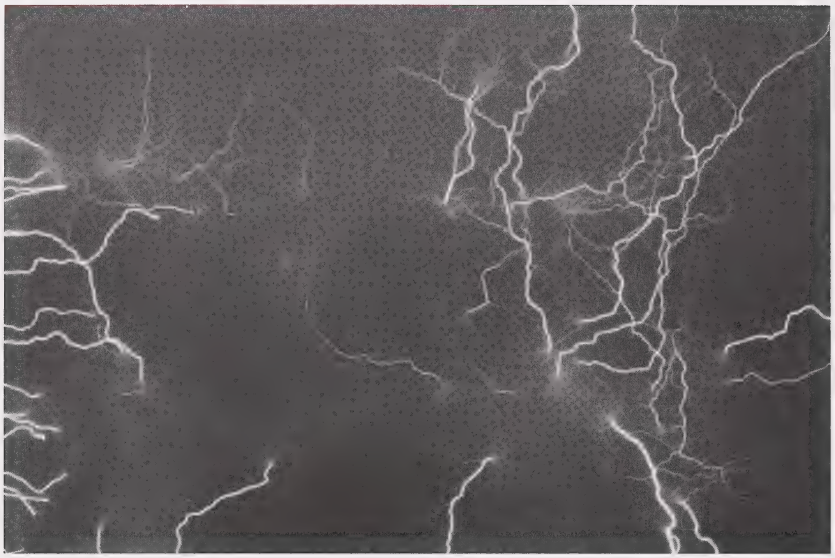
The Nature and Behaviour of Light

Have you ever woken up in the middle of the night and peered out of a window? You would likely remember how dark things appeared—even if the moon was shining or a streetlight was on. Hardly anything would be visible. The view at night is so different from the view before the Sun sets. This contrast makes you aware that the major source of light on Earth is the Sun.

Even though the Sun is the major source of light, there are many other sources you are familiar with. Think of fluorescent lights, a campfire, neon lights, lightning, or a flashlight. These sources may seem different, yet all light sources have things in common. The emitted light from any source is essentially the same and is due to energy conversion at the source.

In this section you will investigate the nature of light and some of its properties to find out how you can use models to explain some natural phenomena that involve light. You will also study natural and artificial sources of light.

Lesson 1: What Is Light?



What if you were blindfolded in a thunderstorm? You would receive only limited information about the storm. Although the sound reaching your ears would give you some sense of the strength and closeness of the storm, actually seeing where the lightning strikes gives a much more complete picture.

Light not only gives you information about the world; it also provides energy. Think of the times you spent relaxing in the Sun and the pleasant warmth the sunshine gave your skin.

Light is at the heart of many human experiences, so it is not surprising that humans have always been curious about light itself.

The following early explanations of light phenomena will likely both amuse and amaze you:

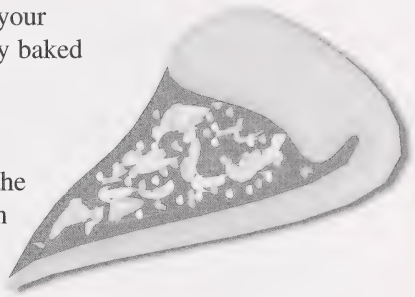
- Pythagoras, a mathematician from the sixth century B.C., proposed that vision occurred when light travelled from a person's eyes and touched things.
- It was once believed that light picks up a colour when it strikes an object.
- Some early scientists believed that luminous objects gave off particles that then travelled to people's eyes.
- In 1675 a new theory stated that light was reflected because light particles bounced off surfaces. Light bent when it entered glass or other transparent material because the material attracted the light particles.

- In 1678 a new theory stated that light was a wave motion of a mysterious, invisible material that existed all around people.

None of these explanations were completely correct. But these explanations kept people interested in learning more about light itself. Nowadays, light is explained as a type of wave.

Radiant Energy

It seems that a piece of pizza that's reheated in your microwave oven tastes almost as good as freshly baked pizza. Would you agree?



A microwave oven generates a certain form of electromagnetic radiation (EMR) that heats up the pizza directly without heating the air in the oven or the plate holding the pizza. The EMR that heats the pizza is microwave radiation.

You were introduced to EMR in Science 7. You likely remember that radiation is energy transfer—in the form of waves—that occurs without any movement of matter. There are many different forms of EMR that include radio waves, X-rays, microwaves, infrared—heat or thermal—radiation, and light. They all share four basic characteristics:

- They behave like waves.
- They can be absorbed, transmitted, or reflected as they interact with matter.
- They travel in straight lines.
- They all travel across empty space at a speed of 300 000 km/s.

Going Further

Thinking of light as a wave is very useful when you're trying to understand the nature of light.

Read pages 238, 239, 244, and 249 of the textbook for more information about waves and how they can be used to represent light.

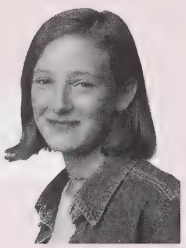
These "Going Further" sections are for those of you who want to do extra in-depth work. There are lots of interesting topics to work on.

Light is a form of radiant energy that stimulates the sensation of vision. When this radiant energy reaches light-sensitive cells in the eye, the cells respond by sending messages to the brain, which then translates them into the images you see. Check Figure 3.53 on page 234 of the textbook. You see an object because of the light it emits or reflects to your eyes.

Read pages 176 and 177 in the textbook for more information on sources of light and the relationship between radiant energy and other forms of energy.

In this lesson, and in the rest of this course, you will be doing written work. You will sometimes be directed to an Assignment Booklet to do this written work. However, for the numbered questions in Student Module Booklets, you should answer the questions in a notebook set aside for Science 8.

I write my answers in my notebook. There's lots of room there.



Also, use the notebook to record results while doing science investigations.

1. Write definitions for the following terms: *light, natural light source, radiant energy, radiate, radiation,* and *artificial light source.*

2. Visible light emitted from any source requires an energy conversion. Name the energy source used to produce light from a flashlight.

3. List three forms of energy that light can be transformed or converted into when it has been absorbed by a surface.

Compare your responses with those in the Appendix on page 57.

The following activity helps you view light as a form of energy that can be absorbed, then converted, into other types of energy.

Find Out Activity Is Light Energetic?

Refer to the activity on page 177 of the textbook.

Follow the steps of "Procedure." If you cannot get a solar-powered calculator, you may omit step 1.

Black film canisters could possibly be obtained from a local film-processing business.

When you do step 2 of "Procedure," use two canisters. Have one covered with aluminum foil and the other uncovered. Feel the inside of both canisters. This will prepare you for question 7 of "Extensions."

4. Answer questions 1 to 7 from "What Did You Find Out?" and "Extensions."

Check your answers with your teacher or home instructor.

Intensity

Do you remember stepping out of a building on a bright, sunny day and having to sneeze? Maybe you didn't sneeze, but one-quarter of people stepping outside into bright light actually do sneeze. In any case, until your eyes adjusted, you experienced some discomfort. It was the sudden change in light **intensity** or brightness that caused your reaction.

intensity: the brightness of light

Light intensity describes the amount of light energy emitted by a source or received by an object. Every light source **emits** a specific amount of energy that radiates outward in all directions like the spokes of a wheel. Refer to the candle diagram on page 178 of the textbook, and read the information at the top of the page.

emit: to give off

Find Out Activity Reading with Intensity

Refer to the activity on page 178 of the textbook.

In this activity you will explore how the intensities of two different sources compare and the effect distance from the source has on intensity.

Carry out the steps in "Procedure." Pay special attention to the safety warnings.

5. Answer the "What Did You Find Out?" questions.

Compare your responses with those in the Appendix on page 57.

Light Sources

Have you experienced a blackout from an electrical power interruption? During a blackout you become aware of how much you depend on artificial sources of light.

Read pages 179 to 183 in the textbook to learn about various sources of light.

6. Write definitions in your notebook for the following terms: *incandescence*, *fluorescence*, *phosphorescence*, *luminous*, and *non-luminous*.

7. How can cities decrease their problems with both light pollution and energy consumption?

8. **a.** What material is used to make the filament of an incandescent light bulb?

b. What percentage of the electrical energy used by incandescent bulbs is released as heat?

Incandescent light bulbs contain a mixture of inert gases, such as argon and nitrogen, to prevent the hot filament from evaporating.

9. Describe one advantage fluorescent light sources have over incandescent sources.

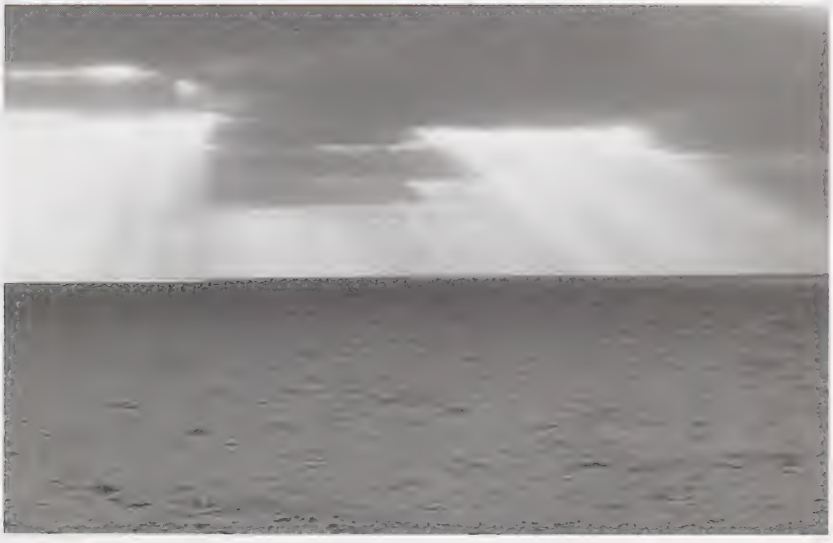
10. Describe the major difference between fluorescent and phosphorescent light sources.

11. Why should fluorescent tubes and TV picture tubes be recycled rather than just thrown away?

12. Compare chemiluminescence and bioluminescence.

Compare your responses with those in the Appendix on page 58.

The Ray Model of Light



ray model: a model of light based on light travelling in straight lines

ray diagram: an illustration that uses straight arrows to show the path of light

On vacation you may have been travelling in a boat or a car with a good view of the horizon. If your journey seems to go on and on, watching the interaction of sunlight and clouds near the end of a day can provide a welcome distraction. When sunlight goes through clouds and dust near the horizon, the sunlight sometimes appears as sunbeams. The straightness of these sunbeams suggests that light travels in straight lines. The idea that light travels in straight lines is the basis of the **ray model** of light.

Turn to pages 184 and 185 of the textbook and read "The Ray Model of Light." Pay attention to Figures 3.11A and 3.11B, which illustrate the drawing conventions and symbols used in a proper **ray diagram**.

13. Which property of light does the ray model make use of to explain the formation of shadows?

14. Write definitions for the following terms: *transparent*, *translucent*, and *opaque*.

Compare your responses with those in the Appendix on page 58.

The pinhole camera is a simple device that can be used to demonstrate that light does travel in straight lines.

Going Further

The pinhole camera was used to create images before the modern photographic camera existed. The earliest versions consisted of darkened rooms with light admitted through a single, tiny aperture in one wall. The image of an outside scene could be projected on the wall across the room from the light-admitting aperture.

You can find more information about pinhole cameras and their construction by typing *pinhole camera* in a search engine like Google™.

Constructing a pinhole camera, and observing a bright object through the camera, is the challenge of the next activity. With more instructions, photographic film, and practice, you can actually use a pinhole camera to take pictures.

Find Out Activity Make a Large Pinhole Camera

Refer to the activity on page 186 in your textbook.

Carry out the steps of "Procedure" or do the "Extension." In the "Extension" a coffee can with a translucent top could be used instead of a tissue box. Except for punching the hole with a small nail, a coffee can involves less work and will probably yield better results than a tissue box.

Note: If you use a large box you may need to find an assistant to move the bright object for you. A clear, lower wattage light bulb or a candle works best for the bright object. Do the activity in a darkened room.

If you use a candle be sure to have an adult present. Open flames can be a fire hazard!

15. Answer questions 1 to 4 of "What Did You Find Out?" Use a simple ray diagram to answer question 4.

Check your answers with your teacher or home instructor.

16. To test your understanding of the concepts in this lesson, answer questions 1, 4, 6, and 7 of "Topic 1 Review" on page 187 of the textbook.

Check your answers with your teacher or home instructor.

Looking Back

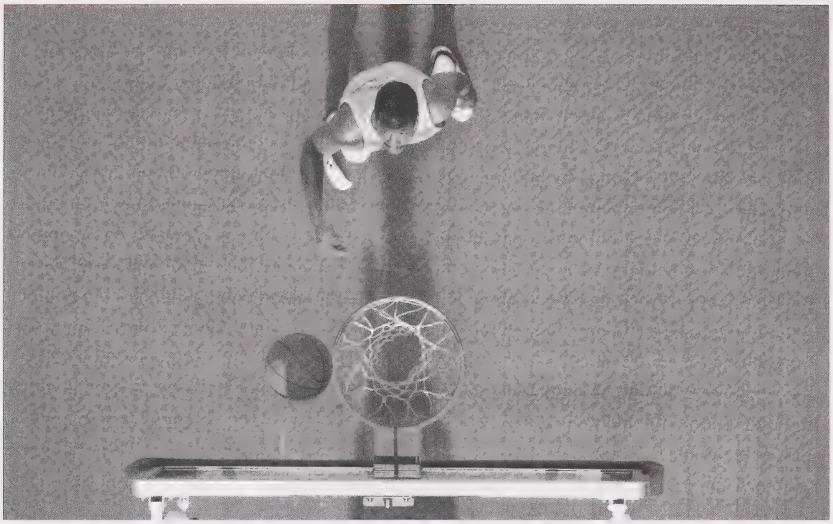
In this lesson you determined that light is a form of radiant energy that travels in a straight line. You discovered that the amount of light reaching a surface depends on the distance from the source as well as the source's intensity. You studied a variety of light sources, both natural and artificial, and found that light is always the result of an energy change.

You used a ray diagram to explain the formation of shadows by opaque objects. Opaque substances prevent light from passing through, translucent substances transmit light but scatter most of it, and transparent substances transmit most of the light without any apparent change.

You observed an upside-down or inverted image on the screen of a pinhole camera that a ray diagram helps you explain. Do you ever wonder how a mirror forms your image? Reflection and image formation are studied in the next lesson.

Turn to Assignment Booklet 3A and complete questions 1 to 7 from Section 1.

Lesson 2: Reflection



When playing basketball, you soon find that the backboard helps you make some shots. When using the backboard you apply what you know about reflection—maybe without even thinking about it.

Turn to page 188 of the textbook. Read the top half of the page for an introduction to the reflection of light.

Reflection is one of the fundamental properties of light. In this lesson you will

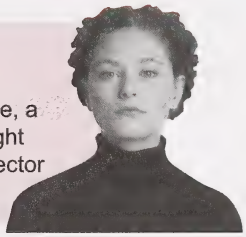
- investigate the reflection of light and other forms of electromagnetic radiation
- verify the laws of reflection
- use ray diagrams to illustrate what happens when light strikes a reflective surface
- use ray diagrams to see how plane mirrors form images
- explore applications of light reflection

Factors Affecting Reflection

Do you know that the characteristics of a surface—such as colour, texture, or lustre—determine what happens when radiant energy like light strikes it?

Oh, yes. I took that in the Science 7 module "Heat and Temperature." Depending on the surface, some energy is absorbed, some is transmitted, and what's left just bounces off as a **reflection**.

reflection: a change in the direction of objects or energy when they strike, then bounce off a surface



Yes, the surface characteristics play an important part in how much of the light is absorbed, sent, and reflected. For example, a dark surface is a better absorber than a light one. And a smooth surface is a better reflector than a rough one.

Read the remainder of page 188 and all of page 189 in the textbook to find out more about reflection and how the ray model of light applies to reflection.

regular reflection: the type of reflection that occurs off a smooth surface

diffuse reflection: the type of reflection that occurs off a rough surface

1. Write definitions for the following terms: *incident ray*, *reflected ray*, *normal*, *angle of incidence (i)*, *angle of reflection (r)*, and *plane mirror*.

Reflection from a mirror is **regular relection**. Reflection from paper is **diffuse reflection**.

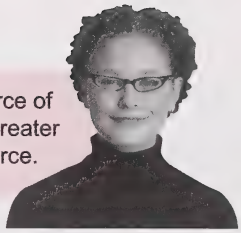
2. Why does a sheet of paper not reflect light like a mirror does?

Compare your responses with those in the Appendix on page 58.

In the next investigation you will examine the relationship between incident rays and reflected rays to determine the **laws** of reflection.

law: the statement of a scientifically observed pattern that has been rigorously tested and never found to have an exception—for example, the law of gravity

The law of gravity states that there is a force of attraction between any two objects. The greater the mass of the objects, the greater the force.



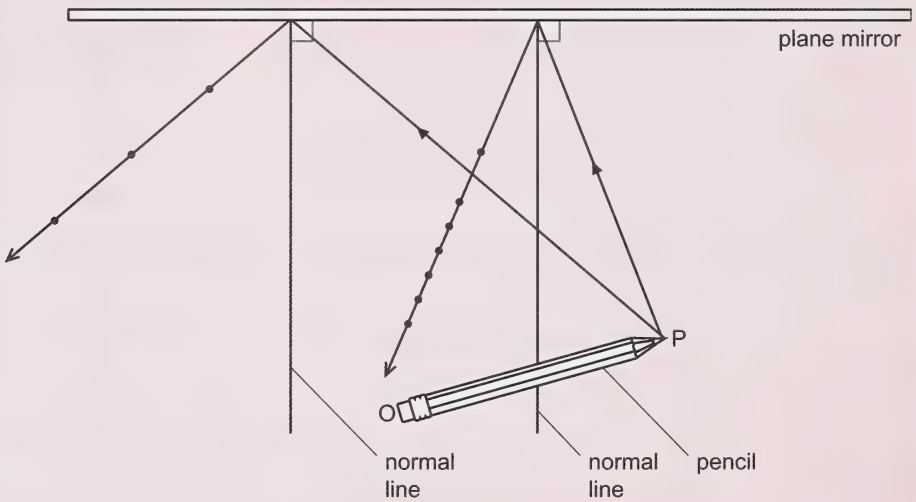
Investigation 3A Inferring the Law of Reflection

Refer to "Inquiry Investigation 3A" on pages 190 and 191 of the textbook. Read the entire investigation to understand its main idea.

To do the investigation you need to hold or support your light source so a beam of light follows along the paper like a pencil line. Place a book behind the mirror to support the mirror perpendicular to your paper.

Note: A ray box is an electrical device that emits a thin beam of light.

Carry out the steps of "Procedure" if you have a ray box. If you don't have a ray box, use the following diagram for steps 1 to 10. Copy the diagram onto the lower half of a sheet of paper.



3. Indicate the angle of incidence and the angle of reflection for each of the two incident rays.

4. Answer questions 2 and 3 of "Analyze."

5. Answer questions 5 and 6 of "Conclude and Apply."

Check your answers with your teacher or home instructor.

When observing images formed by reflection, you see the image because light travels from the object to the reflecting surface and then from that surface to your eyes. In the next investigation you will draw simple ray diagrams to show the path of light from an object to the reflecting surface, and then to your eye.

Investigation 3B When Light Reflects

Refer to "Inquiry Investigation 3B" on pages 192 and 193 of the textbook.

6. Do the steps of "Procedure." Record your observations for steps 3, 6, and 7 in your notebook.

7. Complete questions 1 to 3 of "Analyze" and "Conclude and Apply."

Check your answers with your teacher or home instructor.

Forming an Image

You may have gone to an interview for a part-time job. Aside from being able to talk effectively about your abilities and attitude, having tidy clothing, clean shoes, and combed hair do a lot to give a positive image. Leaving a good impression of yourself may improve your chances of actually landing the job.

Note: The laws of reflection state that the angle of incidence equals the angle of reflection—first law—and that the incident ray, the reflected ray, and the normal ray lie in the same plane—second law.

The image formed by a mirror is really an optical image, rather than an impression left with an interviewer. Nevertheless, the two types of images—optical and the one made in an interview—have something in common: the image of an object made with a mirror is a likeness of the object and the image you leave with the interviewer is a likeness of you.

The image of an object in a plane or flat mirror is formed due to light rays coming to your eye from the mirror. The object appears to be behind the mirror—not where it really is. To explain how images are formed in plane mirrors, you will need to understand the laws of reflection.

Turn to pages 194 and 195 of the textbook and read "Forming an Image."

8. How does the image formed by a plane mirror compare in size to the actual object?

9. You are looking at the image of an apple in a plane mirror. Describe the path the light rays follow for you to see the apple's image.

10. Do two observers in different positions see the same image when they view the image of a stationary object in a plane mirror?

Compare your responses with those in the Appendix on page 59.

Curved Mirrors

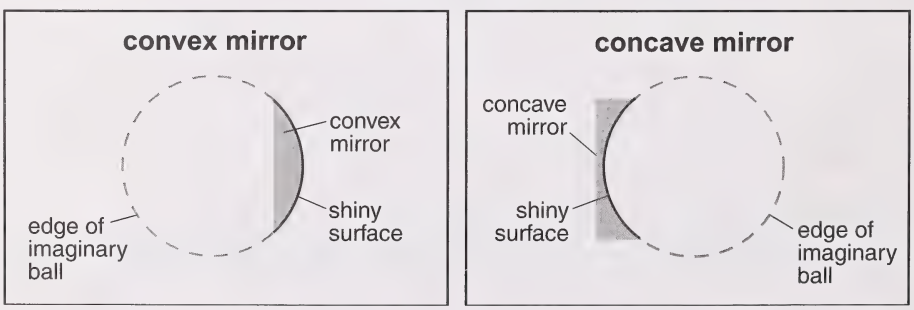
You probably look forward to getting your own driver's licence. First, you have to take a road test from a government-authorized licence issuing office. In the road test you must demonstrate that you have the necessary skills and attitudes to drive safely. If you want to pass the first time, be sure to shoulder check for vehicles when moving from one lane to another.

The side mirror is very helpful to double-check that no other vehicles are in the lane you are moving into. The side mirror is likely a special kind of curved mirror—a **convex** mirror. Such a mirror gives you a wider field of view than a plane mirror.

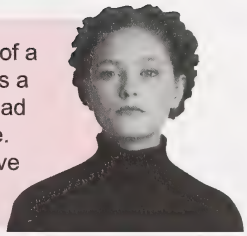
convex: curving outward

Another kind of curved mirror is the **concave** mirror. Shaving or make-up mirrors are often concave. Concave mirrors can magnify the view to give you more facial detail.

concave: curving inward like a cave



A convex mirror is shaped like the outside of a ball because its surface bulges outward. As a result, convex mirrors make light rays spread out so they can be viewed at a wider angle. This is called **divergence**. How are concave mirrors different?



divergence: spreading out

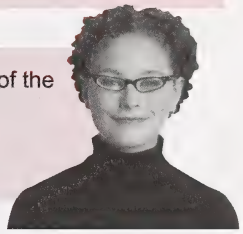
Convex mirrors and concave lenses make light rays diverge.

Concave mirrors are curved inward, like the inside surface of a hollow ball. This shape means that concave mirrors reflect light into smaller, more concentrated areas. These reflections cause the **convergence** of light rays.

convergence: coming together

Concave mirrors and convex lenses bend rays inward. These rays converge at the focal point.

You're right. Depending on the curvature of the mirror, parallel incoming light rays can be reflected away or toward each other. This magnifies or diminishes the image's size.



Going Further

Do you want to actually see images formed by curved mirrors? Refer to the "Find Out Activity: Out of the Looking Glass," on page 196 of the textbook.

Follow the steps of "Procedure." Record your observations.

You find out that the images you see in a convex mirror are smaller than they are in a plane mirror. A concave mirror can project an image onto a screen. It can also be used to make an enlarged image.

Turn to pages 195 and 196 of the textbook and read "Curved Mirrors."

Note: In optics a real image is an image formed when light rays actually meet at the points of the image. A **virtual image** is formed when rays spread out as if from points of an image without actually coming from the image. Virtual images are beyond or on the other side of a reflecting surface.

virtual image: an image located where light rays only appear to originate

It cannot be projected on a screen.

An inverted image is an image that is upside down. When a concave mirror makes a real image, the image is inverted.

11. Objects appear larger or smaller in curved mirrors.

a. What kind of mirror can enlarge an image?

b. What kind of mirror always makes things look smaller?

Compare your responses with those in the Appendix on page 59.

Rough Surfaces

Earlier in the lesson you found that when it's compared to a mirror, a sheet of paper is very rough. In a sense the laws of reflection hold true even for rough surfaces, as long as you apply the laws properly.

Turn to page 197 in the textbook and read "Rough Surfaces." Pay particular attention to Figure 3.22, and note how a ray diagram helps explain regular (A) and diffuse (B) reflection. Remember that to form images light must be reflected uniformly to your eyes or a screen; the light must not be scattered.

12. Explain why diffuse reflection occurs.

Compare your response with the one in the Appendix on page 59.

Going Beyond Human Vision

Imagine being outside when it is dark and still being able to see well. This may not seem possible. It may surprise you that new technologies allow people to obtain images and have vision where it was previously impossible. Think of these two examples.

Did you know that from space it is possible to get detailed images of most regions on Earth? Cameras on orbiting satellites take such pictures. Some of these cameras use radio waves rather than light waves to make an image.

Imagine using infrared light—a form of radiant energy—to make images of things in the dark. This "light" does not make objects visible to the eye, but a special instrument can make an image from the reflected infrared light. This allows people to have super "night vision."

Turn to pages 252 and 253 of the textbook. Read "Remote Imaging Technologies" and "Think About It."

13. To test your understanding of the concepts in this lesson, answer questions 1 to 3 of "Topic 2 Review" on page 199 of your textbook.

Check your answers with your teacher or home instructor.

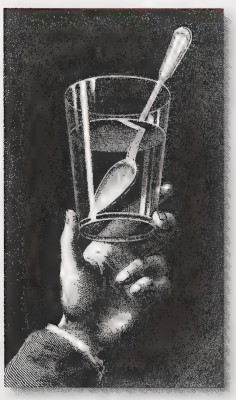
Looking Back

In this lesson you explored reflection from plane and curved mirrors and rough surfaces. You determined that the laws of reflection are true for all types of reflection. You used ray diagrams to locate the image formed by a plane mirror. Through observation you discovered the following:

- Virtual images are formed behind a mirror.
- Convex-mirror images are always virtual, upright, and behind the mirror.
- Concave mirrors can magnify objects close to the mirror.
- Some new technologies can make images using forms of radiant energy other than light.

Turn to Assignment Booklet 3A. Complete questions 8 to 13 from Section 1.

Lesson 3: Refraction



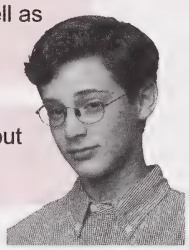
Try to think back to when you used a spoon to mix drink crystals with water. The part of the spoon you see through the water may appear to be slightly out of position.

When a light travels through the boundary or edge of a transparent substance, such as water or a glass, changes to the light occur at the boundary. What happens to the light that passes through the boundary? Could those changes explain why the spoon appears to be displaced? That's the subject of this lesson. You will investigate the path light follows as it is transmitted from one substance into another.

refraction: the change in direction of a ray of light when it passes from one medium into another due to a change in the speed of the light

When light passes from one transparent or translucent substance—a medium for light—into another, it is likely refracted. **Refraction** is a fundamental or basic property of light.

You can perform a simple demonstration to illustrate refraction. First, you will have to get a glass and partially fill it with water, leaving a little space at the top. Stick a finger into the glass of water and, keeping the finger vertical, slowly move it toward and away from you as well as up and down. What do you observe?



The part of the finger in the water seems to move out of alignment with the part above the water.

The effect you observe is due to the bending of light coming off your finger. Remember that you see an object—such as your finger—because light from a source is reflected from the object to your eyes. Figure 3.26 on page 200 in the textbook illustrates the phenomenon. You can imagine that if you were spearing a fish for lunch, you would have to aim lower than where the fish appeared to be or go hungry!

Read the introduction to refraction on page 200 of the textbook for an explanation of why the refraction of light occurs.

1. The speed of light is affected by the substance it travels through.

a. What is the speed of light in air, glass, and diamonds?

b. The densities of these materials are 0.0013 g/mL, 2.6 g/cm^3, and 3.5 g/cm^3, respectively (1 mL = 1 cm^3). Based on the data provided, write a prediction about the relationship between the density of a material and the speed at which light travels through it.

2. Use the concept of refraction to explain why it is likely that a young bear's first salmon-fishing expedition will be unsuccessful.

Check your answers with your teacher or home instructor.

Find Out Activity The Re-appearing Coin

Refer to the activity on page 200 of the textbook.

Follow the steps of "Procedure" with a partner, if possible. Relate your observations to the concept illustrated in Figure 3.26.

3. Answer the question in "What Did You Find Out?"

Compare your response with the one in the Appendix on page 59.

Investigation 3C When Light Refracts

Refer to the "Inquiry Investigation" on page 201 of the textbook.

Carefully read the entire investigation. Then do the steps of "Procedure."

4. Answer questions 1 to 4 of "Analyze" and "Conclude and Apply."

Compare your responses with those in the Appendix on page 60.

Going Around the Bend with Light

Light will bend when it goes from one medium to another. But which way will it bend—toward or away from the normal?

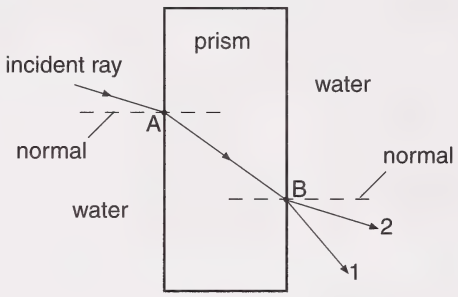
See Figure 3.27 on page 204 of your textbook. Think of a light ray that moves from air, through a rectangular block of glass, and then back into air.

Generally, when light travels from one medium to another that is more dense, the light will bend toward the normal. Going into a less-dense medium, light will bend away from the normal.

Read page 204 in your textbook. Note how the incident ray and the refracted ray change directions at both surfaces in Figure 3.27.

Light bends when going from one material to another. Light bends toward the normal going into a more dense substance and away from the normal going into a less dense substance.

A rectangular prism of an unknown substance is submerged in water. A ray of light enters the prism from the water at point A and is refracted as shown in the diagram.



5. a. Does light travel faster or slower in the prism than it does in the water?

b. Predict the path the refracted ray will follow at B—path 1 or 2?

Check your answers with your teacher or home instructor.

Investigation 3D Follow That Refracted Ray!

Refer to the "Inquiry Investigation" on pages 202 and 203 in the textbook. Read through the entire investigation.

Look at the photo on page 202 to see a ray box. The electrical device in the picture is a ray box, which makes a beam of light. If you don't have a ray box you won't have to actually do the investigation. Sample results will be included so you can still think your way through the investigation.

Follow these general tips if you have a ray box:

- You will need to find a clear container as described under "Apparatus" in the textbook. To avoid distortion, make sure your tray has vertical sides that are quite thin and plain with no designs.
- If you can't get a watertight plastic lid or tray, use a colourless glass container. The sides need to be as straight up and down as possible to decrease distortion.
- A light beam path is easier to observe in a semi-dark room. It is best to turn off overhead lights.
- The addition of a few drops of milk will make the water slightly cloudy. This will allow you to easier see the light beam path.

6. Identify and list your manipulated variable, responding variable, and at least one controlled variable for this science question:

> How does the density of a liquid affect the amount of bending toward the normal?

Suppose you have a way of sending a narrow beam of light through a transparent container. The container is like that in the diagram on page 202. The container is transparent and shaped like a shallow aquarium. You can fill it with various liquids.

7. Write down two questions you could investigate with such an apparatus and materials.

8. Write your hypothesis for an investigation about the refraction of light.

9. Do steps 1 and 2 of "Procedure." Briefly describe your procedure. If you do not have a group to work with, talk about your plans with a friend or family member.

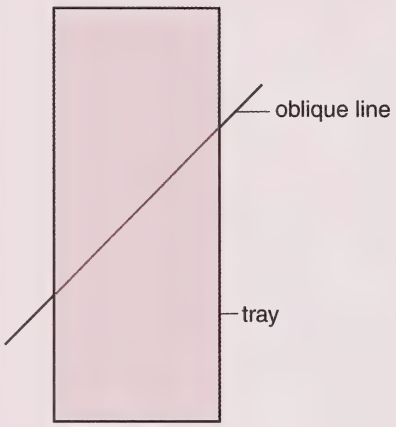
Note: When preparing actual-size diagrams to record your observations, start one diagram in the following way:

Step 1: Draw an oblique straight line on the sheet of paper. Make your line long enough so that it will extend beyond the parallel sides of the tray when the tray is in position.

Step 2: As part of your procedure, make a light ray beam follow the line as it enters the tray. Trace the path of the beam coming out of the tray.

Step 3: Compare the traced path of the exiting beam to the position of the line you drew earlier.

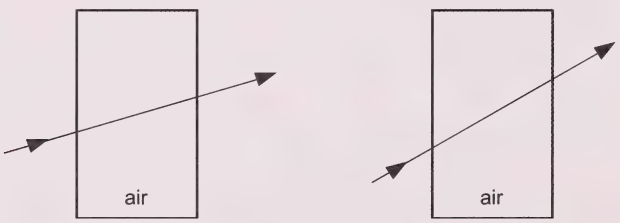
Ray Diagram



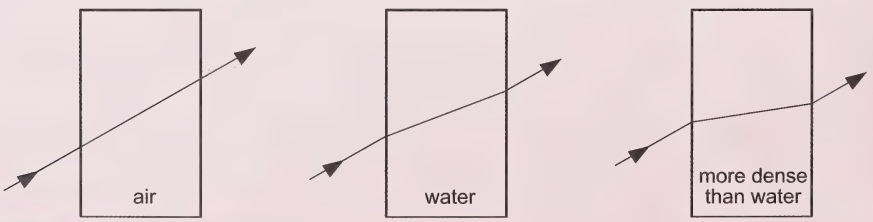
As you do your investigation, complete the following questions. If you are just thinking your way through the investigation, base your answers on the information provided.

10. Sketch diagrams as outlined in steps 4 (a), (b), and (d) of "Procedure," or study the following diagrams.

The path of a light ray going through an empty tray is as follows.

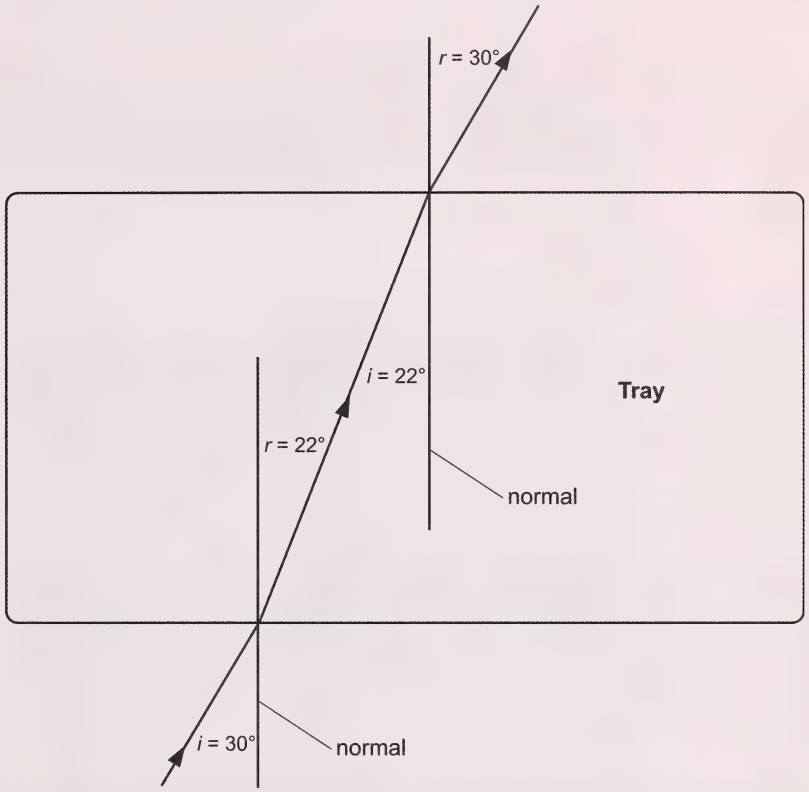


The path of the same light ray is shown—from left—going through an empty tray, a water-filled tray, and a tray filled with a more dense liquid.



11. Do questions 2 and 3 of "Analyze" or just study the following diagram if you are not physically doing the investigation.

Path of the Light Through a Tray



Check your answers with your teacher or home instructor.

To find out how to dispose of the liquids you used, talk to your teacher or home instructor.

Going Further

You have likely observed a glass prism or a glass ornament that projects rainbow colours onto a wall. The colours appear due to refraction. The study of refraction led to the discovery that white light, such as sunlight, is actually a mixture of colours. Isaac Newton demonstrated this.

Do you want to learn more about white light, colour, and the interaction of light with coloured surfaces? Then read pages 228 to 230 of the textbook.

12. To test your understanding of the concepts in this lesson, answer questions 1 to 5 of "Topic 3 Review" on page 206 of the textbook.

Check your answers with your teacher or home instructor.

Going Further

Practise your investigative skills as you learn more about light. Complete questions 8 and 9 on page 206 of the textbook. Note that you will need your instructor's approval to actually do an investigation.

Looking Back

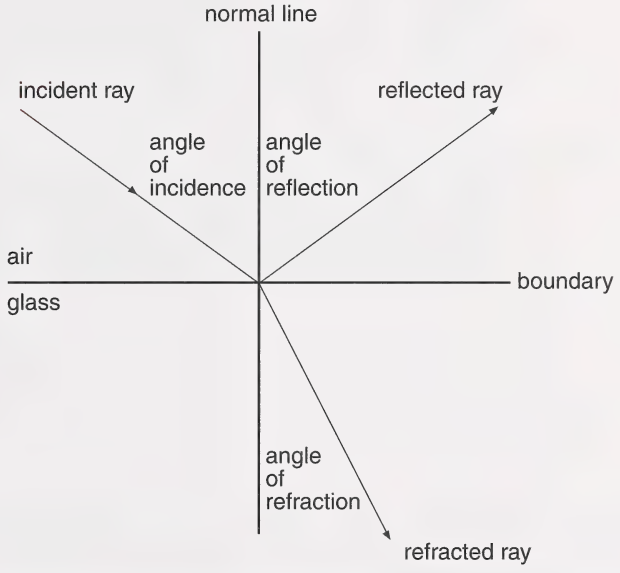
In this lesson you observed that light is refracted when it passes through a boundary, a surface, or an edge between two optically different, transparent substances. In other words, a ray of light is bent. From observations, you reasoned that moving from a less dense substance to a denser substance causes light to bend toward the normal line as it slows down. Moving from a more dense substance into a less dense substance, light bends away from the normal line as it speeds up.

Section Review

Do the following questions to review the concepts covered in this section.

1. Turn to page 207 in the textbook. Answer questions 1 to 6 under "Wrap-up: Topics 1 to 3."

2. How do the angles of refraction and reflection compare to the angle of incidence in the following diagram?



Compare your responses with those in the Appendix on page 61.

Conclusion

In this section you discovered light is a form of radiant energy that is emitted from a variety of sources and it normally travels in a straight line. Light can be absorbed, reflected, transmitted, and refracted by matter, depending on the nature of the material and its surface.

You verified the laws of reflection. You also found that the path of light bends at the boundary of substances that differ in density.

From observations, you found that plane, concave, and convex mirrors form images. By using the ray model of light, you analysed how plane mirrors form images.

The next time you see an image due to reflection, whether in a mirror or a pond, you will have a better understanding of this marvellous event.

Turn to Assignment Booklet 3A and complete questions 14 to 18 of Section 1.

Section 2

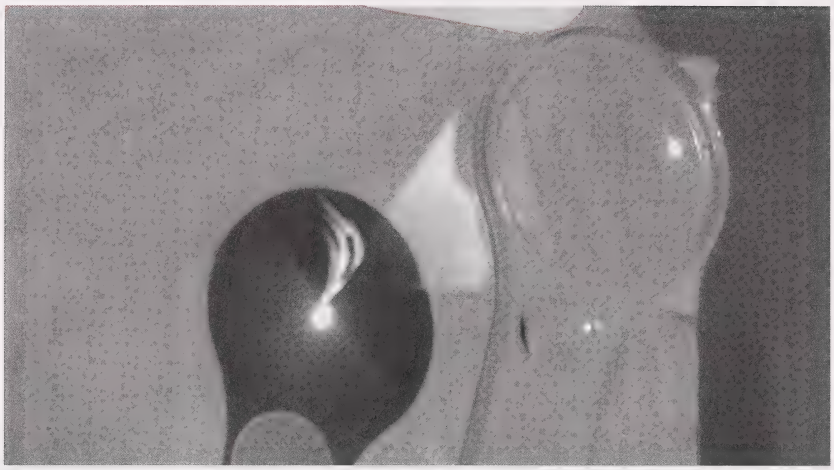
Vision and Optical Devices

Think back to when you woke up this morning. From the moment you opened your eyes, did you start seeing objects around you?

Interpreting visual information about your world involves reflection, absorption, and the transmission of light. The sense of vision is a natural application of the properties of light. Optical devices use the same properties to extend human vision.

In this section you will explore the roles refraction and reflection play in vision and optical devices.

Lesson 1: Lenses and Vision



It's summer and you're on a hiking trip. You're setting up camp in the mid-afternoon for an overnight stay. You have your gear but forgot to bring matches. However, you did carry a magnifying lens with you to examine small mountain-meadow flowers. Can you use the lens to start a fire?

The photo shows a magnifying lens that is concentrating sunlight onto a small spot. This spot is an image of the Sun. In this small spot the sunlight is converted into thermal energy. It becomes very hot—hot enough to start burning.

focus: to bring light to a point; to bring rays of light together to produce a clear image

There are also lenses in your eyes and in cameras. These lenses **focus** light at one point that is called the **focal point** of the lens. By focusing light, these lenses make images.

In this lesson you will study how lenses create images and how images form in your eyes. You will also compare the make-up of the human eye to that of the camera.

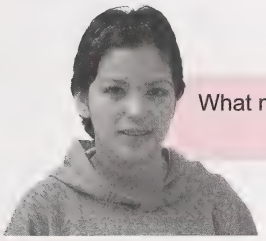
focal point: the point at which parallel rays reflected by a mirror or refracted by a lens meet or appear to meet

Play the *Science 8 Multimedia* CD, provided to you on the inside cover of Module 1, on a computer. Once the first screen appears, select the title "Real Images." This will give you an introduction to how a lens can form an image on a screen. **Note:** Don't try to remember all the details.

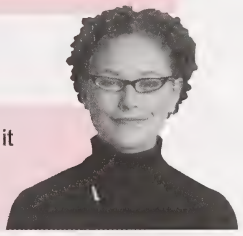
Types of Lenses

Light rays refract as they enter and come out of glass. That's because glass is a medium that is denser than air. A piece of glass with rounded surfaces can make light rays converge or diverge. This specially shaped piece of glass is a lens.

Turn to page 208 of the textbook and read the top half of the page.

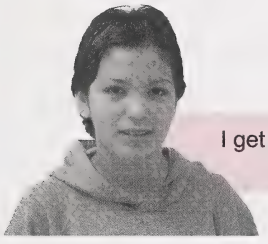


What makes light bend through lenses the way it does?



Light bends toward the normal as it enters the lens material and away from the normal as it leaves.

The lens faces are like parts of a sphere, so all incoming parallel light rays diverge or converge to a point. And the more the surfaces are curved, the closer the focal point is to the lens.

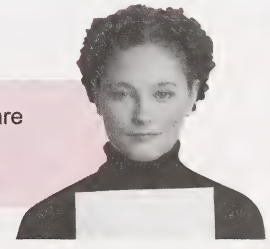


I get it. The greater the curvature, the stronger the lens.

1. Write definitions for the following terms: *lens*, *concave lens*, and *convex lens*.

2. Refer to Figure 3.29 on page 208 of the textbook. Explain why a light ray passing through the centre of either lens does not bend.

Compare your responses with those in the Appendix on page 62.



Try the following to quickly compare what effect concave and convex lenses have on light.

Hold a concave lens over the words on this page. Move the lens slowly up and down at a variety of distances until you see a clear image. Now try the same procedure using a convex lens.

Find Out Activity See for Yourself!

Refer to the activity on page 208 of the textbook.

Follow the steps of "Procedure." Record your observations in your notebook.

3. Why does a single drop of water work better as a convex lens than does a larger amount of several drops?

4. Answer the questions from "What Did You Find Out?"

Compare your responses with those in the Appendix on page 63.

The Eye and the Camera

Read pages 210 and 211 of the textbook to find out what lenses do in the eye and a camera. You will also discover how lenses are used to improve vision.

5. Muscles in the eye change the shape of the lens to view both distant and nearby objects. The contraction of these muscles lengthens and thins the lens. Predict whether the lens would thicken or thin to view a distant object. Explain your prediction or use a ray diagram to support your prediction.

6. **a.** Define *far-sighted.*

   b. How is far-sighted vision corrected?

7. **a.** Define *near-sighted.*

   b. How is near-sighted vision corrected?

   c. Eyeglasses can be made of either glass or plastic. This fact led a student to ask the following question: Is plastic the best optical material to use in eyeglasses? Rephrase the student's question so that it can be tested.

8. Create a table that compares the functions and components of a camera to those of the human eye. Include the terms *aperture*, *eyelid*, and *pupil* in your table. Try to infer the function. Read ahead on pages 215 to 219 if you are unsure of the functions.

Note: Some eyeglasses are made of "high-index" material that allows the lens curvature to be small and the lens to be thin but still provide strong correction.

9. Read "Cool Tools" on page 214 of the textbook. How does a digital camera differ from the camera you just analysed?

Compare your responses with those in the Appendix on page 63.

In the next investigation you will learn how a basic camera works. This investigation should be done under the supervision of an adult because it involves fire.

Investigation 3E The Camera

Refer to the "Inquiry Investigation" on pages 212 to 214 of the textbook.

Read the beginning of the investigation. "Prediction" is about the distance you need between the lens and a screen to have a sharp image of an object. Think about this: Does this distance have to change when the object comes closer to the lens?

Avoid any risk of accidental fire. Ask your teacher or home instructor to help you whenever you are using the candle.

Follow steps 1, 2, and 3(a) of "Procedure" from "Part 1."

10. Answer step 3(b) of "Procedure."

Follow step 3(c).

11. Continue with steps 1 and 2 of "Procedure" from "Part 2." While you do the steps, place your data in the table made in question 10.

12. Complete question 1 of "Analyze."

Check your answers with your teacher or home instructor.

Turn to Assignment Booklet 3B. Complete question 1 from Section 2.

Going Further

Take "Investigation 3E" a little further! Try "Math Connect" and "Computer Connect" on page 214 of the textbook.

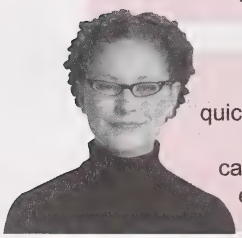
Putting It in Focus

The way the eye and the camera focus, collect light, and "see" the image of an object is similar.

My camera is a fixed-focus camera. It will not let me take close-ups, but it does well on regular shots.

Typically for fixed-focus cameras, you have to make sure that what you are taking a picture of is more than two metres away. If it's closer than that the photo will be fuzzy. In other words, it will be out of focus. To take close-up shots you need a camera with an adjustable focus. Such a camera is generally a bit more expensive than a fixed-focus camera.

If our eyes are like cameras, they are remarkable because they are better than fixed-focus cameras. Not only do our eyes focus on objects both near and far—they do so automatically.



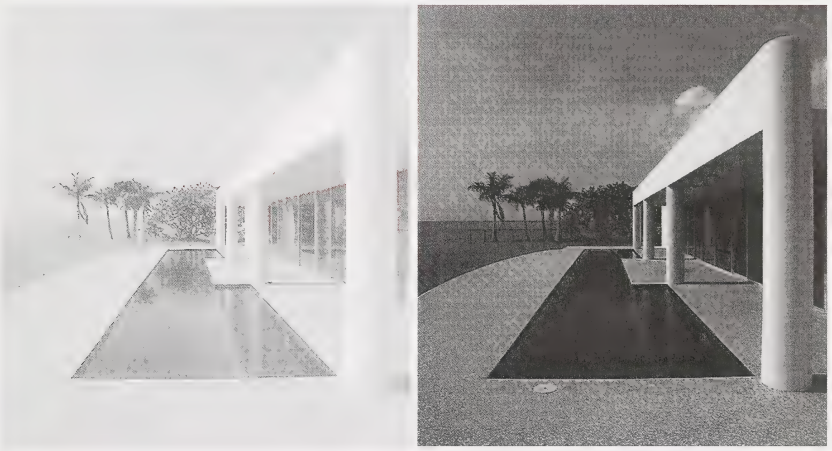
That's right! Your eyes focus very effectively and quickly. Maybe that's because the focusing mechanisms of your eyes are different than the mechanisms in a camera. To compare the focusing mechanisms of your eyes and a camera, read page 215 in your textbook.

13. Define the following terms: *accommodation*, *near point*, and *far point*.

14. What is both the near point and the far point for an adult with normal vision?

Compare your responses with those in the Appendix on page 64.

Letting in the Light



You may have seen a photograph in which everything is too light or too dark. A camera needs to admit the proper amount of light in order to work; if not, photos look overexposed or underexposed.

You may have found everything hard to see after coming indoors on a bright, sunny day. This illustrates that your eye must also admit the proper amount of light. Otherwise, your vision suffers.

Read page 216 and the top of page 217. You will learn how the amount of light entering a camera or an eye is controlled.

15. Define the following terms about vision: *diaphragm*, *aperture*, *shutter*, *iris*, *pupil*, and *iris reflex*.

Compare your responses with those in the Appendix on page 64.

Seeing the Image

Read the rest of page 217, all of page 218, and "Career Connect" on page 220 of the textbook.

16. How is the area at the "blind spot" different from the rest of the retina?

17. What purposes do the aqueous and vitreous humours have in the eye?

18. What does an optometrist do?

Laser Light

Did you know that laser light is involved when you play music on a CD or watch a DVD movie? A laser beam is used to read the information from the spinning disk.

In your textbook, laser light is described as a coherent light. To understand the idea of coherence you need to understand the wave model of light. This goes beyond what is expected of Science 8 students.

Just accept that because laser light is coherent light, it is stronger than normal light and can be brought to a sharper focus. Because of these special properties, laser light is used in eye surgery.

Turn to pages 246 and 247 of the textbook and read "Laser Light."

19. List two ways in which laser light is used in eye surgery.

Compare your responses with those in the Appendix on page 65.

Are all eyes created equal? Different environments and lifestyles demand specially adapted optical equipment. The more you "look" at eyes and their associated structures, the weirder the structures become.

To start your investigation of what may sometimes seem like science fiction, read "Did You Know?" on pages 231 and 254 of the textbook and "Off the Wall" on page 234.

20. See if you can answer these trick questions.

a. What colour is the grass that deer eat? Explain your answer.

b. Will that fish truly appreciate your colourful new swimsuit? Explain your answer.

c. Should bumblebees wear sunglasses with UV protection? Explain your answer.

Compare your responses with those in the Appendix on page 65.

Have fun thinking about these trick questions.

How many eyes does a spider have? What about a fly? Can a jellyfish see? Are bird eyes superior to those of humans? Can bats see in the dark? Why are octopus eyes exceptional?

Find out more interesting and weird things as you do the next investigation!

Investigation 3F What an Eyeful!

Refer to the "Think and Link Investigation" on page 219 of the textbook.

21. Use the investigation, except step 3 of "What to Do," as a guide to research and to compare the eyes of a different type of animal. If you are not in a science class, then share your findings with your family, your friends, and your instructor.

Present your answers to your teacher or home instructor.

Going Further

To learn about light-based technology careers, try "Internet Connect" on page 220 of the textbook.

22. To test your understanding of the concepts in this lesson, answer questions 1 to 4 of "Topic 4 Review" on page 220 of your textbook.

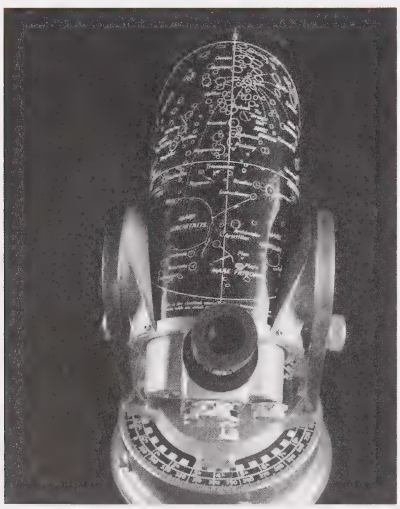
Check your answers with your teacher or home instructor.

Looking Back

In this lesson you investigated how concave and convex lenses affect light, and you also studied how these lenses correct eye defects. You then looked at the structure and function of both the parts of the eye and a camera. You also investigated the intriguing eyes of a variety of animals.

Turn to Assignment Booklet 3B. Complete questions 2 to 5 from Section 2.

Lesson 2: Extending Human Vision



Gaining knowledge about the world has been a human quest since ancient times. Optical instruments such as telescopes and microscopes are applications of lenses and mirrors for gathering the information light provides about the world around you. Optical instruments have allowed human vision to be extended into both the macrocosm—the universe—and the microcosm, which is the microscopic world.

Telescopes and Binoculars

Telescopes and binoculars bring distant objects into view more clearly. These instruments function in a similar way. Light is gathered and focused to produce an image of the object. The major difference between telescopes and binoculars is the length of the tube through which light travels to the observer's eyes.

For more details about these devices, read pages 221 to 224 in the textbook.

1. Write definitions for the following terms: *refracting telescope*, *objective lens*, *eyepiece lens*, *reflecting telescope*, and *objective mirror*.

2. How was the telescope likely invented?

3. What is the major difference between a refracting telescope and a reflecting telescope?

4. Describe the structure and function of a Heads Up Display (HUD).

Compare your responses with those in the Appendix on page 65.

Going Further

Are you interested in space exploration technology? Try "Internet Connect" on page 221 of the textbook.

Go to the following website:

http://www.school.mcgrawhill.ca/resources

After selecting "Sciencefocus 8," click continue .

In order, click "Unit 3: Light and Optical Systems," "Topic 5: Lenses and Vision," "Internetconnect," and, finally, click "Internetconnect."

This takes you to "INTERNETCONNECT, page 221," where you will find links for the Hubble Space Telescope.

Find Out Activity Make Your Own Refracting Telescope

Refer to the activity on page 222 of the textbook.

You may be able to use or modify the lens set-up you made in "Inquiry Investigation 3E: The Camera."

You may place one lens in a frame as shown in the textbook or support the lens in modelling clay. For the second convex lens you may use a magnifying lens.

Follow the steps of "Procedure."

5. Complete the questions from "What Did You Find Out?"

Compare your responses with those in the Appendix on page 65.

Microscopes, Telescopes, and Scientific Knowledge

Briefly review the structure and function of the compound light microscope on pages 106 and 107 of the textbook. For information on how the telescope and microscope contributed to the accumulation of scientific knowledge, read page 224 in the textbook.

6. Use point form to list two major contributions to scientific knowledge gained through the use of each of the following:

a. telescopes
b. microscopes

Compare your responses with those in the Appendix on page 66.

Find Out Activity Making a Microscope

Refer to the activity on page 226 of your textbook.

Follow the steps of "Procedure" to build a microscope. Use the same two lenses you used to construct a telescope in "Find Out Activity: Make Your Own Refracting Telescope" on page 222.

7. Answer the questions in "What Did You Find Out?"

Compare your responses with those in the Appendix on page 66.

8. To test your understanding of the concepts in this lesson, answer questions 1 to 3 of "Topic 5 Review" on page 226 of the textbook.

Check your answers with your teacher or home instructor.

Looking Back

In this lesson you investigated the structure and function of binoculars, telescopes, and microscopes. You also described the role of optical instruments in the growth of scientific knowledge.

Section Review

Do the following questions to review the concepts covered in this section.

Turn to page 227 in the textbook. Answer questions 1, 2, 4, 5, and 7 of "Wrap-up: Topics 4 to 5."

Check your answers with your teacher or home instructor.

Conclusion

NASA/STScI

In this section you investigated the properties of light to explain the functioning of a biological organ—the eye—and the development of light-based technologies that extend human vision and scientific knowledge.

The newly installed Advanced Camera for Surveys (ACS) aboard NASA's Hubble Space Telescope is one example of the newest light-based technologies. The image on this page was taken with the ACS on April 2, 2002. Until that date, such views of deep space had not been possible. The Cone Nebula is 2500 light-years away from Earth.

The picture shows "just" the upper 2.5 light-years of the nebula. This distance equals over 20 million round trips to our Moon. For the source of this information, check the following website:

http://hubblesite.org/newscenter/archive/2002/11

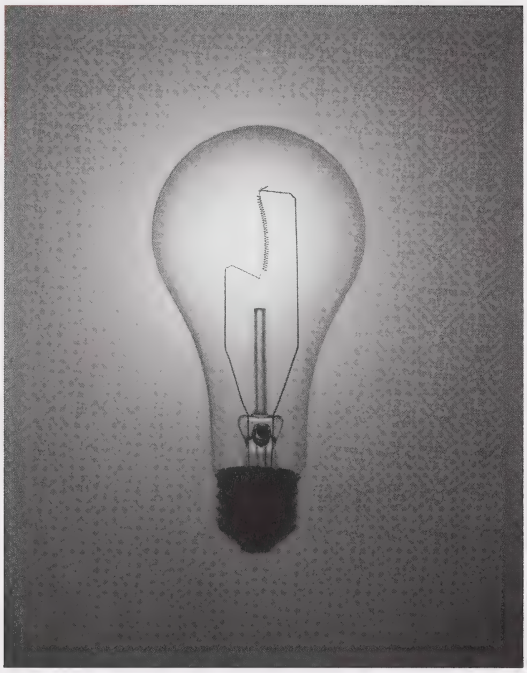
Turn to Assignment Booklet 3B. Complete questions 6 to 8 from Section 2.

Module Summary

In this module you explored the nature of visible light and discovered how the ray model of light helps you to understand the phenomena of reflection and refraction. You also investigated the role that lenses and mirrors play in image formation and the extension of human vision. You also learned how light-based technologies contributed to the accumulation of scientific knowledge.

Thin, transparent fibres of glass or plastic can transmit light throughout their length by internal reflections. Doctors can use this technology to carry images from body cavities that could otherwise not be visually examined. Fibre optics is just one of the many new light-based technologies that has extended human vision. The understanding of light and its behaviour brings powerful optical tools within your grasp.

Module Review



To review the concepts covered in this module, turn to page 262 in the textbook. Go over the concepts listed under "Unit at a Glance."

1. To help test your understanding of the concepts covered in this module, answer the "Unit 3 Review" questions 1 to 3, 6, and 27 from pages 262 to 264.

Check your answers with your teacher or home instructor.

Turn to Assignment Booklet 3B and do the Final Module Assignment.

SCIENCE 8

APPENDIX

Glossary

Suggested Answers

Image Credits

Glossary

absorption: the process of taking in incident radiant energy and transforming this energy into another form

accommodation: an automatic adjustment of the lens in the eye to bring images of objects from various distances into focus on the retina

angle of incidence (i): the angle between the incident or incoming ray and the normal

angle of reflection (r): the angle between the reflected or outgoing ray and the normal

angle of refraction: the angle between the refracted ray and the normal

aperture: the opening in a camera that lets light in

artificial light source: a human-made light energy source, such as fluorescent light tubes

bioluminescence: the emission of visible light by living organisms

chemiluminescence: the giving off of visible light from a chemical reaction without an apparent change in temperature

coherent light: light consisting of waves all lined up and of the same wavelength

Laser light is coherent light.

concave: curving inward like a cave

concave lens: a lens that is thinner in the middle than at the edges causing refracted rays to spread out or diverge

convergence: coming together

Concave mirrors and convex lenses bend rays inward. These rays converge at the focal point.

convex: curving outward

convex lens: a lens that is thicker in the middle than at the edges causing refracted rays to bend toward each other or converge

cosmology: the study of the overall structure of the physical universe

diffuse reflection: the type of reflection that occurs off a rough surface

The reflection of light is in all directions from a rough surface.

diaphragm: the camera component that changes the size of the aperture and, therefore, the amount of light entering the camera

dispersion: the spreading of white light into the full spectrum of colours

divergence: spreading out

Convex mirrors and concave lenses make light rays diverge.

emit: to give off

energy: the ability to do work

Energy exists in several forms, such as chemical, kinetic, radiant, and thermal energy.

erect image: an upright image

eyepiece lens: the magnifying lens or lenses of a microscope or telescope

far point: the greatest distance at which an object is in focus

far-sighted: unable to focus the image of a nearby object on the retina because the eyeball is too short

fluorescence: the emission of visible radiation by particles of a substance after having absorbed high-energy radiation, such as invisible ultraviolet radiation

focal point: the point at which parallel rays reflected by a mirror or refracted by a lens meet or appear to meet

focus: to bring light to a point; to bring rays of light together to produce a clear image

incandescence: the emission or giving off of visible radiation—light—by a hot object

incident ray: any ray of light travelling toward a reflecting surface; an incoming ray

intensity: the brightness of light

inverted image: an upside-down image

iris: the band of muscle in the eye that controls the pupil's size

iris reflex: the automatic change in the pupil's size in response to varying light conditions

laser: a narrow, high-energy coherent beam of light that will travel long distances without spreading out

Laser is the acronym for **l**ight **a**mplification by the **s**timulated **e**mission of **r**adiation.

law: the statement of a scientifically observed pattern that has been rigorously tested and never found to have an exception—for example, the law of gravity

law of reflection: the law stating that the angle of incidence equals the angle of reflection, and that the incident ray, the reflected ray, and the normal lie in the same plane

lens: a curved piece of glass, plastic, or other transparent material used to make light rays converge or diverge

light: a form of radiant energy that stimulates vision

luminous: matter that emits light energy

macrocosm: the universe

microcosm: the universe in miniature

natural light source: light from a non-human-made source, such as sunlight, bioluminescence, or fire

near point: the shortest distance at which an object is in focus

near-sighted: unable to focus the image of a distant object on the retina because the eyeball is too long

non-luminous: matter that does not give off light; its image is formed from reflected light only

normal: a reference line drawn perpendicular to a reflecting surface at the point where an incident ray strikes the surface

objective lens: the convex, light-gathering lens in a refracting telescope or microscope that forms a real, inverted image of the object near the eyepiece lens or lenses

objective mirror: the mirror that gathers and focuses light in a reflecting telescope

opaque: not capable of transmitting rays of light

The human eye cannot see objects through an opaque material.

ophthalmology: the study of the eye and its diseases

optics: a branch of science concerned with the nature and origin of light

phosphorescence: the persistent sending out of visible light after exposure to—and the removal of—a source of radiation

plane mirror: a flat mirror

power: the rate at which energy is converted or at which work is done; measured in watts (W)

prism: a triangular piece of glass that can be used to separate white light into the colours of the spectrum

A prism is used in binoculars to reflect and invert the image.

pupil: the opening in the eye where light enters

radiant energy: energy emitted or transferred in the form of waves, such as light or infrared radiation

radiate: to send out or emit energy in the form of waves

radiation: radiant energy transfer

ray diagram: an illustration that uses straight arrows to show the path of light

ray model: a model of light based on light travelling in straight lines

real image: an image actually formed by rays of light

It can be projected on a screen and formed using a concave mirror or convex lens with the object relatively far from the device.

reflected ray: any ray of light that bounces off or travels away from a reflecting surface; an outgoing ray

reflecting telescope: a telescope that uses a concave mirror to gather and focus light from a distant object

reflection: a change in the direction of objects or energy when they strike, then bounce off a surface

refracting telescope: a telescope that uses a convex lens to gather and focus light from a distant object and a concave lens to magnify the image

refraction: the change in direction of a ray of light when it passes from one medium into another due to a change in the speed of the light

regular reflection: the type of reflection that occurs off a smooth surface

retina: the light-sensitive tissue layer at the back of the eye

shutter: the camera component that opens briefly to let light through the aperture

translucent: transmitting, but scattering, rays of light

The human eye cannot clearly see objects through a translucent material.

transmission: the process in which radiant energy, such as light, penetrates and passes through a substance

transparent: transmitting rays of light

The human eye can clearly see objects through a transparent material.

virtual image: an image located where light rays only appear to originate

A virtual image cannot be projected on a screen.

Suggested Answers

Section 1: Lesson 1

1. Light is a form of radiant energy that stimulates vision.

A natural light source is light from a non-human-made source, such as sunlight, bioluminescence, or fire.

Radiant energy is energy emitted or transferred in the form of waves or rays, such as light, sound, or infrared radiation.

To radiate is to send out or emit energy in the form of waves.

Radiation is radiant energy transfer.

An artificial light source is a human-made light energy source, such as fluorescent light tubes.

2. The energy source used is chemical energy stored in the battery.
Comment: This chemical energy is converted into electricity—it is then converted into heat and light.

3. Light energy can be converted or transformed into other forms of energy, such as electrical, thermal, chemical, or kinetic energy.

5. Textbook questions 1 to 3 of "What Did You Find Out?" from page 178:

1. The intensity of the light reaching the pages was reduced as the distance from the bulb increased.

2. It is easier to read the words with light from the 100 W bulb. The light from the 100 W bulb was brighter—more intense—at a greater distance from the source.

3. One way of showing intensity is by the number of lines radiating from the source. The 100 W bulb would have more lines radiating from it than from the 60 W bulb. The distance between the lines increases with the distance from the bulb, which is the source of light. More lines—rays of light—would strike a surface close to the source than would strike a surface farther away.

6. Incandescence is the emission or giving off of visible radiation—light—by a hot object.

   Fluorescence is the emission of visible radiation by particles of a substance after having absorbed high-energy radiation, such as invisible ultraviolet radiation.

   Phosphorescence is the persistent sending out of visible light after exposure to—and the removal of—a source of radiation.

   Luminous matter emits light energy.

   Non-luminous matter does not give off light; its image is formed from reflected light only.

7. Cities can use lower energy streetlights designed to direct light downward to decrease both light pollution and energy consumption.

8. **a.** The filament of an incandescent light bulb is made of tungsten.
   b. Approximately 95% of the energy emitted by incandescent bulbs is given off as heat.

9. Fluorescent light sources use less electrical energy because less energy is transformed into thermal energy. The energy given off by incandescent light sources is mostly thermal energy.

10. In fluorescent light sources, ultraviolet radiation is absorbed by phosphor particles that immediately release visible light. Phosphorescent particles store the radiant energy for some time and emit light over a longer period. The phosphorescent particles glow after the energy source has been removed.

11. The mercury vapour and phosphor coating in these tubes make them toxic.

12. Chemiluminescence is the emission of visible light as a result of a chemical reaction without an apparent change in temperature. Bioluminescence is the emission of visible light by living organisms—often by converting a chemical energy source.

13. Light travels in straight lines.

14. A transparent material transmits rays of light. The human eye can clearly see objects through a transparent material.

    A translucent material transmits rays of light but scatters them; the human eye cannot clearly see objects through a translucent material.

    An opaque material does not transmit rays of light. The human eye cannot see objects through an opaque material.

Section 1: Lesson 2

1. An incident ray is any ray of light travelling toward a reflecting surface. It's an incoming ray.

   A reflected ray is any ray of light that bounces off or travels away from a reflecting surface. It's an outgoing ray.

A normal is a reference line that is drawn perpendicular to a reflecting surface at the point where an incident ray strikes the surface.

An angle of incidence (i) is the angle between the incident ray and the normal.

An angle of reflection (r) is the angle between the reflected ray and the normal.

A plane mirror is a flat mirror.

2. A sheet of paper is quite rough when it's compared to the surface of a mirror. Much of the light is scattered as it's reflected from the rough surface, so an image of the object is not formed—that is diffuse reflection.

8. The size of the image formed by a plane mirror is the same size as the actual object.

9. You are able to see the apple's image because light rays are reflected from the apple's surface, travel in straight lines to the mirror, and are then reflected to your eyes.

10. When two observers in different positions view the image of a stationary object in a plane mirror, they are seeing the same image. The image appears to be formed in the same location, regardless of the observer's position.

11. **a.** A concave mirror can make images appear larger.

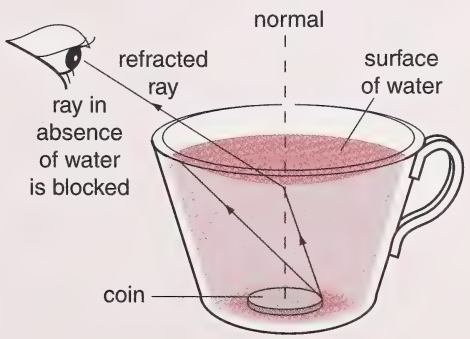
b. A convex mirror always makes things appear smaller.

12. On a rough surface the normal lines point in a variety of different directions. Incoming parallel rays will be reflected in many directions. The rays will be scattered randomly. This will break up the original visual pattern so the rays cannot form an image.

Section 1: Lesson 3

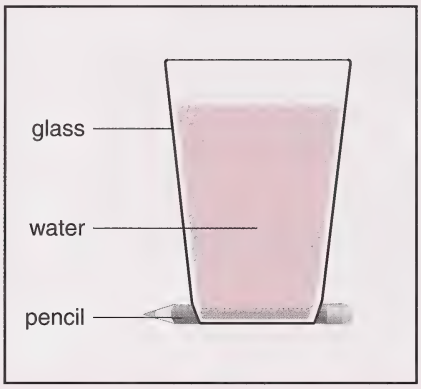
3. **Textbook question from "What Did You Find Out?" on page 200:**

The rays of light changed direction. They were bent by the water. The bent ray got past the rim, allowing you to see the coin again. A ray diagram shows this.

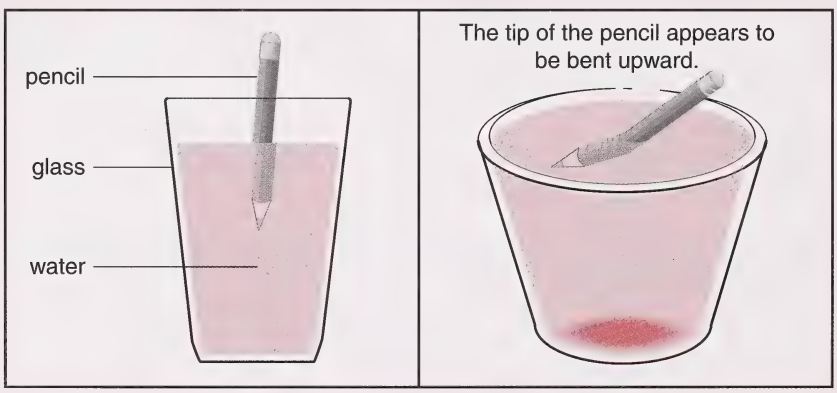


4. Textbook questions 1 to 4 of "Analyze" and "Conclude and Apply," page 201:

1. The pencil was lying flat on the table, with the ends visible on either side of the glass. Light from the ends travelled only through the air. Light from the middle of the pencil travelled through air, plastic, water, plastic, and back into the air. This light did not travel in a straight line. You know this because the middle part of the pencil appeared bent, as in the following sketch.



2. Light from the bottom of the pencil travelled through water, plastic, and air. The light did not travel in a straight line. When the light moved from the water into air it was bent. This makes the pencil appear to be broken at the water's surface, as in the sketch on the left.



3. Light travels through three different media in this activity—these are air, plastic, and water. The effect of plastic is not noticed because the cup is not very thick.

   Note: You may want to compare viewing the pencil through the empty plastic cup and through an empty, but thick, drinking glass.

4. The path of light changes direction during refraction. The image of the object appears to be bent or broken.

Section 1: Review

1. Textbook questions 1 to 6 from "Wrap-up: Topics 1 to 3," page 207:

1. The following words in column B, "Term," should match the phrases in column A, "Description."

Description	Term
the bending of light as it passes from one medium to another	**refraction**
can be transformed into chemical energy, electrical energy, or thermal energy	**light**
allowing no light to pass through	**opaque**
an artificial light source	**incandescent bulb**
a type of diagram explaining how light travels	**ray diagram**
occurs when light bounces off a surface	**reflection**
describes objects that produce their own light	**luminous**

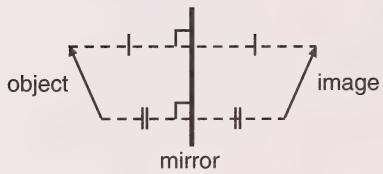
2. Answers will vary. Make shadow puppets to show that light travels in straight lines. Use a solar-powered calculator or a toy without a battery backup to demonstrate that light is a form of energy.

3. Answers should be similar to the following ones.

Sources of Light		
Source	**Process (This is extra information not asked for in the question.)**	**Example**
natural	nuclear or chemical reactions	**sun, fire**
incandescent	object heats until it emits light	**incandescent light bulb**
fluorescent	ultraviolet radiation makes particles of a substance glow—fluorescent tubes use mercury to produce UV radiation to make phosphor coating emit visible light	**fluorescent tubes**
phosphorescent	particles absorb radiant energy and release over a period of time	**watch dials, some minerals**
chemiluminescent	light emitted during a chemical reaction without a change in temperature	**glow sticks**
bioluminescent	form of chemiluminescence found in living organisms	**jellyfish, fireflies**

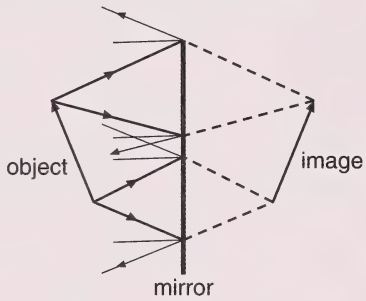
4. The following two ray diagrams show how a plane mirror produces an image.

Locating Image by Distances



object length = 32 mm
image length = 32 mm

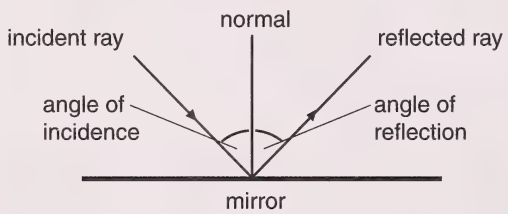
Locating Image by Extending Reflected Rays



object length = 32 mm
image length = 32 mm

Note: There are really two laws of reflection. See textbook glossary, page 531, for "laws of reflection."

5. The angle of incidence equals the angle of reflection. The normal, the incident ray, and the reflected ray are all in the same plane.



6. Answers will vary.

   (a) A dull, black, rough surface will absorb almost all of the incident light.
   (b) A shiny, smooth, light-coloured surface will reflect most of the incident light.

2. Because the light is entering a denser medium, the angle of refraction is less than the angle of incidence—the light bends toward the normal. The angle of reflection would equals the angle of incidence.

Section 2: Lesson 1

1. A lens is a curved piece of glass, plastic, or other transparent material used to make light rays converge or diverge.

   A concave lens is a lens that is thinner in the middle than it is at the edges. It causes refracted rays to spread out or diverge.

   A convex lens is a lens that is thicker in the middle than it is at the edges. It causes refracted rays to bend toward each other or converge.

2. The light ray going through the centre of either lens is perpendicular to the surface of the lens material, which is made of glass. For this light ray the angle of incidence is 0°. For this angle there is no change in the direction of the light ray due to refraction.

3. A single drop of water has a curved surface. A larger number of drops has a flat surface.

4. **Textbook questions 1 and 2 from "What Did You Find Out?" on page 208:**

   1. A convex lens is used to make a magnifying glass.

   2. Answers will vary. Samples follow.

      (a) A concave lens causes radiant energy to diverge. This lens could be used in a car headlight or in a lantern.

      (b) A convex lens causes radiant energy to converge. This lens could be used in a spotlight or in a narrow beam flashlight.

5. A thinner convex lens causes less refraction. To see distant objects, the eye muscles contract. This thins the lens—less refraction is necessary to focus the image. For nearby objects the muscles relax, causing the lens to thicken. More refraction is necessary to focus the image.

6. **a.** Being far-sighted means you're unable to focus the image of a nearby object on your retina because your eyeball is too short.

   b. Far-sighted vision is corrected with a convex lens.

7. **a.** If you're near-sighted you're unable to focus the image of a distant object on your retina because your eyeball is too long.

   b. Near-sighted vision is corrected with a concave lens.

   c. Answers may vary. The question should be similar to this: What effect does the type of plastic (MV) have on the angle of refraction (RV)?

8. The following is an example of how your table could look.

Comparing Structures		
Function	**Camera Component**	**Eye Component**
allows light in	**aperture**	**pupil**
controls amount of light entering	**diaphragm**	**iris**
opens and closes to let light in or prevent it from entering	**shutter**	**eyelid**
refracts light to focus image	**rigid lens**	**flexible lens**
light-sensitive screen for image formation	**film**	**retina**
adjusts lens for near and far objects	**focusing ring**	**ciliary muscle**

9. Digital cameras do not use film. Images are stored on a silicon chip as a series of electrical charges. The brighter a point of the image, the higher the stored electric charge. A computer measures the resulting design of tiny electrical charges and converts them into binary numbers—these are the codes computers use to recreate the images.

13. An accommodation is an automatic adjustment of the lens in the eye to bring images of objects from various distances into focus on the retina.

    The near point is the shortest distance at which an object is in focus.

    The far point is the greatest distance at which an object is in focus.

14. The near point is 25 cm, and the far point is infinity.

15. The diaphragm is the camera part that changes the size of the aperture and, therefore, the amount of light entering the camera.

    The aperture is the opening in a camera that lets light in.

    The camera part that opens briefly to let light through the aperture is the shutter.

    An iris is the band of muscle in the eye that controls the pupil's size.

    The opening in the eye where light enters is called the pupil.

    The iris reflex is the automatic change in the pupil's size in response to varying light conditions.

16. The retina has no cells that sense light at the blind spot. This is the point where the optic nerve enters the retina.

17. The fluids or humours keep the eye from collapsing and help to refract light entering the eye.

18. An optometrist prescribes lenses to correct vision problems.

19. Laser light is used in eye surgery to

    - put a detached retina back into place
    - shape a cornea to correct vision problems

20. **a.** Deer see only black and white colours, so the grass they eat must be gray.

    b. Fish have a highly developed sense of colour, so any truly fashion-conscious fish will have an opinion.

    c. If bumblebees wore sunglasses, they would not be able to detect the ultraviolet radiation patterns that help them identify flowers.

Section 2: Lesson 2

1. A refracting telescope uses a convex lens to gather and focus light from a distant object and a concave lens to magnify the image.

   An objective lens is the convex, light-gathering lens in a refracting telescope or microscope that forms a real, inverted image of the object near the eyepiece lens or lenses.

   An eyepiece lens is the magnifying lens or lenses of a microscope or a telescope.

   A reflecting telescope uses a concave mirror to gather and focus light from a distant object.

   The mirror that gathers and focuses light in a reflecting telescope is an objective mirror.

2. It is likely that the telescope was invented by accident when Hans Lippershey, a Dutch optician, was testing some of his lenses.

3. The refracting telescope uses a convex lens to gather light and form a real, inverted image near the eyepiece. The reflecting telescope uses a concave mirror for this purpose.

4. A Heads Up Display reflects light through a prism to create an image in front of a person's eyes.

5. **Textbook questions 1 to 4 from "What Did You Find Out?" on page 222:**

   1. Answers will vary. The image appears to be larger than the object.

   2. The image is inverted; it's upside down.
      Note: For astronomical observations an inverted image is not a problem. In terrestrial or land telescopes an additional lens is used to make the image appear upright.

3. The lens in the eyepiece of a refracting telescope has the greater curve.

4. The waxed paper can be used as a screen. By moving the paper back and forth between the lenses, you can find the location of the small, real, inverted image. The larger image you see is virtual—you cannot find it on a screen.

6. **a.** Contributions gained through the use of telescopes were these:

   - an accurate value of the speed of light
   - an enormous amount of information about the universe

   b. The following were gained through the use of microscopes:

   - the discovery of cells and micro-organisms and their features
   - the knowledge that the shape and size of crystals affects the strength and hardness of metals

7. **Textbook questions 1 to 3 from "What Did You Find Out?" on page 226:**

   1. Answers may vary and they depend on approximations. The image should be larger than the object by a factor greater than 1.

   2. The image is inverted.

   3. The objective lens usually has the greater curvature in a microscope.

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